DJW

Application/Control Number: 10/739,207

Art Unit: 2858

Title of the Invention – The Voltage Dosimeter –

System and method for

supplying variable voltage

to an electric circuit.

Inventor - Adolph Mondry

753 Virginia

Plymouth, Michigan, 48170

(734) 459-6267

Citizenship – United States of America

CROSS REFERENCES TO RELATED APPLICATIONS

001 Adolph Mondry – System and method for automatically maintaining a blood oxygenation level. P.N. 5,682,877, November 4, 1997 – herein referred to as 877. The flow sheets of that device are similar to those of the Voltage Dosimeter.

002 Meland Kantak – Internal fuel staging for improved fuel cell performance. P.N. application 20020081479 – herein referred to as 479. A similar device is used in the Voltage Dosimeter.

003 Thomas L Cable – High performance fuel cell interconnect with integrated flow paths and method for making same. P.N. application 200300877498 – herein referred to as 498. A similar device is used in the Voltage Dosimeter.

FEDERALLY SPONSORED RESEARCH GRANTS

004 There are no Federally sponsored research grants available to those involved in the research and development of this device.

BACKGROUND OF THIS INVENTION

005 Fuel cells and many devices that are voltage producing sources, such as solar cells, must constantly generate the full amount of voltage needed to operate all connected circuits. Connections between these devices will be needed as requirements expand. It is desirable to have a device available, which automatically controls circuit voltage to minimize the need for constant voltage generation in fuel cells and other voltage producing devices without compromising circuit function; and which provides automatic switching.

BRIEF SUMMARY OF THE INVENTION

006 It is an object of the present invention to provide a method and apparatus to control voltage in fuel cells and other voltage producing sources to produce and deliver appropriate varying circuit voltage to decrease voltage production by placing the negative electrode of the voltage producing source in a predetermined range. It is a further object of this invention to provide automatic switching between these devices to provide extra voltage when needed.

007 In carrying out the above objects and other stated objects and features of the present invention a method is provided as a Voltage Dosimeter for maintaining a desired voltage level at the negative electrode (herein named the entrance voltage) of a voltage producing source, and includes delivering a first voltage producing dose to the positive electrode (herein named the exit voltage) of the voltage producing source producing an exit voltage dose selected from one of a plurality of exit voltage doses between a first exit voltage dose and a second exit voltage dose. The method includes delivering a second voltage producing dose to the circuit <u>connected to the device</u> while repeatedly sequencing through the plurality of sequential exit voltage doses beginning with the first exit voltage dose and proceeding to an adjacent exit voltage dose in the sequence after a predetermined time

interval has elapsed. The second voltage producing dose is delivered until the entrance voltage level attains the desirable level, at which point corresponding exit voltage and voltage producing doses are selected from the plurality of sequential voltage producing and exit voltage doses. The method also includes delivering the selected exit voltage and voltage producing doses so as to maintain the desired entrance voltage level.

008 In the preferred embodiment the method automatically selects an appropriate reactive gas dose to maintain a desired entrance voltage level of a fuel cell, for which the system is particularly suited, and is the preferred voltage producing source, and includes delivering a first reactive gas flow rate to the fuel cell, producing an exit voltage dose in the fuel cell selected from one of a plurality of exit voltage doses between a first exit voltage dose and a second exit voltage dose. The method includes delivering the second reactive gas flow rate to the fuel cell while repeatedly sequencing through the plurality of sequential exit voltage doses beginning with the first exit voltage dose and proceeding to an adjacent exit voltage dose in the sequence after a predetermined time interval has elapsed. The second reactive gas flow rate is delivered until the entrance voltage attains the desirable level, at which point a corresponding exit voltage dose and reactive gas flow rate are selected from the plurality of sequential exit voltage doses and reactive gas flow rates. The method also includes delivering the selected exit voltage

dose and the reactive gas flow rate so as to maintain the desired entrance voltage level.

009 The advantages of the Voltage Dosimeter are minimal needs for constant voltage production in fuel cells and other voltage producing sources, the availability of switching voltage values between these devices as the need arises, and a reduction in the cost of electricity.

010 The above objects, features, and other advantages will be readily appreciated by one of ordinary skill in the art from the following detailed description of the best mode for carrying out the invention, when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

011 Fig. **1/6** demonstrates a perspective view of the first embodiment of the present invention.

012 Fig. **2/6** is a graphical demonstration of the flow charts of the Voltage Dosimeter.

013 Fig. **3/6-5/6** are flow charts dealing with the voltage and reactive gas strategy of the present invention for use in the Voltage Dosimeter.

014 Fig. **6/6** is a flow chart for relating parameters in the Voltage Dosimeter.

DETAILED DESCRIPTION OF THE INVENTION

015 Referring now to Fig. **1/6**, a first embodiment of the present invention is shown. This embodiment indicated by reference number **1** in Fig. **1/6** is the best mode in implementing this invention and is particularly suited for use as a Voltage Dosimeter. Figure **1/6** includes two voltimeters **2** and **3** - one voltimeter **2,** which measures exit voltage – v1 at the positive electrode **4** of a voltage delivery system and a second voltimeter **3,** which measures entrance voltage – v2 – at the negative electrode **5** of a voltage delivery system. Two band pass electrical filters **7** and **8** are connected to each voltometer **2** and **3,** then to an electronic control unit (ECU) **9**, which exercises control strategy, and processing and analyzing voltage data to maintain v2 in a specific range. The ECU **9** preferably operates on power delivered from either D.C. or A.C.power supplies allowing portability to the Voltage Dosimeter System.

016 With continuing reference to Fig. **1/6** a fuel cell **10** as described in U.S. patent application 498 is added as the preferred embodiment of a voltage delivery system. The two reactive gas flow rates at the inlets **11** are controlled by two ECU **9** controlled variably opening solenoid valves **12** with Coulomb controlling circuits, as was taught in 877 and United States P. N. 5,008,773. Reactive gases pass through an electrolyte solution **13**, then react at the electrodes **14**. A typical reaction is $2H_2+O_2=2H_2O+4e^-$+heat, thus producing

voltage in an electric wire **15** with resistance **16**. A circuit **6**, such as that of a family dwelling, is pictured. Adequate voltage delivery here is the object of the present embodiment. A battery **17** is supplied for use when extra power is needed. Optional DC/AC converters **17** and AC//DC converters **6** are included for better use of conventional appliances.

017 Referring now to Fig. **2/6**, the method of device function is demonstrated graphically. Negative electrode voltage is placed on the ordinate and time, reactive gas flow rate, voltage producing dosage and positive electrode voltage are placed on the abscissa of a Cartesian plane. Maximum <u>or minimum </u>reactive gas flow rate or voltage producing dosage occurs at tR on the abscissa, the significance of which will be presented later. Measured and calculated logarithmic functions are used in the preferred embodiment as exit voltage doses, but any measured and estimated transcendental function with an inverse may be used.

018 Referring again to Fig. **1/6**, as will be seen, conditions on v2 – the entrance voltage - control reactive gas flow rate **11** and thus v1 - exit voltage, circuit voltage, circuit voltage dosage, and finally entrance voltage – v2 – itself.

019 Referring now to Fig. **2/6**, the illustrated method of reactive gas flow rate and exit voltage dosage selection starts with the administration of an extreme reactive gas flow rate – herein referred to as the selector dose of the

reactive gas flow rate which produces a local maximum or minimum voltage producing and exit voltage dose at the positive electrode of the fuel cell or of any voltage producing device – as in curve A or B. Curve A is represented by y=log to the base a of x. Curve A activates at x=0. <u>It is named Max R</u>

020 Line CG is the desired voltage of v2 – herein referred to as the selection parameter, which is a range in the actual device. <u>Curve B is a reflection of Curve A across Line CG. It is named Min R.</u> At the intersection of line CG and curve A or B (call it X), line D points to point E on the abscissa as the selected reactive gas flow rate or voltage producing dose. This is determined by graphical means and, as will be seen, the flow charts. <u>Which curve intersects first determines which one is used.</u> The virtual exit voltage dose logarithm is curve F, which activates at point E, the selected voltage producing dose, and is boosted by curves A, B, H – an overshoot of curve A – and curve I – a deactivation of curve H – to produce line G, which is the selected exit voltage dose and here is an exit voltage as well, because it is a horizontal line, and is represented by y=log to the base b of tr , where tr is the t value of the flattening out of the logarithm y=log to the base b of t (curve F) at tr seconds by line G. Line G is completely determined by the intersection (X) described above and in the flow charts, as will be seen, thus the determination of lines F and G by the above methods is unnecessary. Curve F and G start in the x coordinate system at x=t and in the t coordinate

system at t=0, when curve A deactivates. Curve F and G deactivate when curve A activates. Curve J is the virtual curve of curves A and H. K marks the Circulation time. It marks the time from the initial reactive gas flow rate to the first recording of v1. Its accuracy is essential for proper flow chart function with respect to time. Its calculation and that of tr will be demonstrated. The voltage producing dose is circulation time dependent. The exit voltage dose is not, since it is a function of time. At line CG v1 usually differs from v2 in value. At the above mentioned intersection (X) v2 is in its desired range and v1 is selected as the selected exit voltage dosage, which determines the selected voltage producing dosage.

021 Before describing the flow charts it is useful to explain the terminology employed. The most recent base state keeps v2 (the entrance voltage) in its desirable range. V1 (the exit voltage) and v2 are measured in all states. The washout state washes out overshoots. For the fuel cell Voltage Dosimeter exit voltage doses are functions of reactive gas flow rates. For other voltage producing devices, exit voltage doses are functions of other voltage producing dosage mechanisms - motion, magnetism, heat or technologies producing heat.

022 Referring now to Fig. **3/6-5/6**, flow charts are shown, which illustrate the system and method for the proper selection of exit voltage doses, voltage producing doses, and reactive gas flow rates.

023 Referring to Fig. **3/6,** Step **400** determines various system parameters, which may be predetermined and stored in memory, calculated by an ECU (such as ECU **9** in Fig. **1/6**) or entered by a system operator. The system parameters include the following:

MIN R=minimum dose of exit voltage given for each range.

MAX R=maximum dose of exit voltage given for each range.

V1=exit voltage.

Range=flow charts with different durations of increments.

IR=available dose increments for each range.

V2=entrance voltage. When it equals zero for ten seconds, the device deactivates and reactivates when the battery discharges in response to the closing of a circuit switch.

Tv1=desired exit voltage.

dL=low v2 threshold.

dH=high v2 threshold.

TSS=series state delay time.

Tcirc=circulation delay time.

Twash=washout delay time.

tR=desired response time or reaction time

To calculate dH and dL close all circuits. Increase v1 until all circuits first function properly. Measure v2. Do the same with the smallest circuit.

Compare v2. The larger voltage is dH. The smaller voltage is dL. For ties add or subtract circuit devices.

024 As shown in Figure **3/6** the ECU now passes control to Step **402,** which measures v1 and v2. At Step **404** a maximum exit voltage dose of the last range is administered. This is represented graphically by curve A of Figure **2/6** and is called the selector dose. It represents the maximum exit voltage dose. The possible exit voltage dose is set for the lowest dose of the lowest range, which is the first dose in a sequence of possible exit voltage dosages from the lowest to the highest dose.

025 With continuing reference to Figure **3/6** at Step **406** v1 is maintained while pausing Tcirc seconds, then x is set to 0 seconds. Step **406** is called an adjustment state. It coordinates the flow charts with respect to time. Initial circulation times may be estimated or measured.

026 Referring once again to Figure **3/6** the ECU passes control to Step **408**, which continues to deliver exit voltage to v1. Step **408** is referred to as a series state -Tss – and is necessary to coordinate the progression through various possible doses within a time period determined by tr. The calculation of Tss depends on the current operating state. Some representative calculations are illustrated in Figure **6/6** for a single ranged implementation as discussed in greater detail below.

027 Still referring to Figure **3/6** a test is performed at Steps **409** and **410.** It asks – is v2 greater than dH? – and, is v2 less than dL?, respectively. They split control into three pathways. Negative answers to both conditions direct control to Step **426**, where 1. The current exit voltage dose is set to the possible dose and directs the voltage producing dose to its abscissal value in the Cartesian plane.2. A pause for the circulation time does not take place, because there is none here, because all space inferior to line G of Figure **2/6** is flooded by the space above it. Then, 3. t is set to 0. This represents voltage producing dose and exit voltage dose selection. This occurs at x=tR, the reaction time.

028 Now referring to Figure **4/6** processing continues with the ECU directing control to Step **428**, which pauses to washout high valued functions from the selected dose. The state is completed when all involved functions equal a straight line – the selected exit voltage dose – then this dose is activated. The exit voltage dose remains the selected dose as line G in Figure **2/6**. Both of the above dosages continue until activation of MIN R or MAX R. Step **430** measures voltage values for the Conditions below. Steps **432** and **433** represent a second test and ask the same questions as the above mentioned first test – Is v2 greater than dH or less than dL, respectively? If either answer yes, control is directed to Steps **431** and **434,** respectively, where a predetermined fraction of tr is either subtracted or added,

respectively to tr. This pathway determines tr only if the circulation time is correct. The circulation time is calculated by keeping the last three base state values in memory. When control is directed to or beyond a noncontiguous base state from which control was originally assumed a predetermined amount of time is added to the circulation time. This will correct abnormally short circulation times. For abnormally long circulation times – if control passes consecutively to two ascending or descending base states, a predetermined amount of time is subtracted from the circulation time.

029 Referring now to Figure **5/6,** if both conditions in the second test answer no, the ECU places control in Step **436**, the base state. Steps **438** and **440** represent the third test and ask the same questions (is v2 > dH or < dL?) as those of the previous tests with different consequences. They determine the stability of the base state (both conditions answer no if it is stable). If it is unstable, the ECU directs control to either Step **463,** if Step **438** answers yes, or **446,** which 1. Minimizes or maximizes the current dose, respectively 2. Pauses for the circulation time, then 3. sets x=0. These doses continue until dose selection. It should be noted that Steps **431, 434,** the yes part of **418,** and the no part of Steps **433** and **440** all yield control to Step **436**, the base state. The ECU then directs control from Step **463** to Step **411,** and from Step **446** to Step **412**.

030 Referring again to Figure **3/6**, the ECU directs control from Step **464** (evaluated later), and if Step **414** in Figure **4/6** (the first condition of fourth test to be elucidated soon) answers no, to Step **408** to maintain the current exit voltage dose for Tss. Control is then directed to Step **409**, which, if along with Step **410** - the first test – the answer is yes to both conditions, control is passed to Steps **411** and **412**, respectively, which decrement and increment the possible dose, respectively, then both pass control to Condition **414**.

031 Referring now to Figure **4/6**, Steps **414** and **418** represent the fourth and final test with different conditions than the other tests. These conditions ask if the present possible dose is the last dose available, and if the present range is the last one available, respectively. If Step **414** answers no, control is directed by the ECU to Step **408** in Figure **3/6**, which maintains a current dose for Tss. If the condition answers yes, control is directed to Step **418**, which determines if the present range is the last range available. If it answers no, control is directed to Step **464,** in which control enters a new range, sets the current exit voltage and voltage producing dose to MAX R or MIN R of the new range, pauses for the circulation time, then sets x=0. Control is then directed to Step **408**, which maintains a current exit voltage dose for Tss. If Step **418** answers yes, the ECU directs control to Step **436**, the base state.

032 Referring now to Figure **6/6** a flow chart is shown illustrating representative calculations of Tss according to the present invention. One of these calculations or an analogous calculation is performed for each series state of Figure **3/6-5/6**, such as illustrated at Steps **408, 411,** and **412**.

033 Returning to Figure **6/6** at Step **480** a test is performed to determine if the system has reached a base state. If not, the series state delay is estimated as: Tss=tr/IR. If the result is true, the process continues with Step **484**, where a test is performed to determine whether v2<dL. If true, then Step **486** determines whether the most recent base state is a minimum for the current range. If it is true, the series state delay is calculated by Step **488** as Tss=tr/(IR-1). Step **498** then returns control to the series state which initiated the calculation.

034 With continuing reference to Figure **6/6,** if the test at Step **486** is false, then the series state delay is calculated by Step **490** as Tss=tr(MAX R-MIN R)/(IR-1)(MAX R-BASE STATE) before control is released to the series state via Step **498.** If the test performed at Step **484** is false, then Step **492** performs a test to determine if the most recent base state is the maximum for the current range. If the result of Step **492** is true, then Step **496** calculates the series state delay as Tss=tr/(IR-1). Control is then returned to the appropriate series state via Step **498.** If the result of the test at Step **492** is false, then the series state delay is calculated by Step **494** as

Tss=tr(MAX R-MIN R)/(IR-1)(BASE STATE-MIN R). Step **498** then returns control to the appropriate series state. Figure **6/6** applies to a single range. One of ordinary skill in the art should appreciate that the calculations may be modified to accommodate a number of possible ranges.

035 It should be apparent to any one skilled in the art that the flow charts provide a method and apparatus for a Voltage Dosimeter.

036 Other Voltage Dosimeters use other means to produce voltage. Fission reactors, mechanical/magnetic reactors, fusion reactors, solar cells, steam/turbine reactors, and fossil fuel burning reactors can function as Voltage Dosimeters controlling voltage in corresponding circuits by the same method and with the same apparatus as the fuel cell Voltage Dosimeter. The range used for v2 depends on the application. Switching function between voltage producing devices employs Step **418** of Figure **4/6** – last range available? - If it answers yes, control passes to Step **436,** the base state, where voltage passes from the device. For all other steps, voltage is transferred to the device.